TMDLS FOR TURBIDITY, CHLORIDE, SULFATE, AND TDS IN THE BOEUF RIVER AND BAYOU MACON BASINS, AR

FINAL
March 3, 2005

TMDLS FOR TURBIDITY, CHLORIDE, SULFATE, AND TDS IN THE BOEUF RIVER AND BAYOU MACON BASINS, AR

Prepared for

EPA Region VI
Water Quality Protection Division
Permits, Oversight, and TMDL Team
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EXECUTIVE SUMMARY

Section 303(d) of the Federal Clean Water Act requires states to identify waterbodies that are not meeting water quality standards and to develop total maximum daily pollutant loads for those waterbodies. A total maximum daily load (TMDL) is the amount of a pollutant that a waterbody can assimilate without exceeding the established water quality standard for that pollutant. Through a TMDL, pollutant loads can be allocated to point sources and nonpoint sources discharging to the waterbody.

The study area for this project consists of the Boeuf River and Bayou Macon basins in southeastern Arkansas. For both basins, the headwaters begin southeast of Pine Bluff and the general drainage pattern is southward into Louisiana. The study area comprises the Arkansas Department of Environmental Quality (ADEQ) Planning Segment 2A and is located entirely within the Delta ecoregion. The study area is about 86% cropland (mostly soybeans, cotton, and rice). The majority of the soybeans and cotton are irrigated, and essentially all of the rice is irrigated. The primary source of irrigation water is the alluvial aquifer, which has high concentrations of dissolved minerals in some areas.

A total of six reaches in the Bayou Macon and Boeuf River basins are included on the Arkansas 303(d) list as not supporting the aquatic life use due to exceedances of water quality standards for either siltation/turbidity, chloride, sulfate, or total dissolved solids (TDS) as shown in Table ES.1. The applicable numeric water quality standards for these reaches are 75 NTU for turbidity (because ADEQ considers all six reaches to be “channel-altered”), 90 mg/L chloride for Boeuf River, 48 mg/L chloride for Big Bayou and Oak Bayou, 411 mg/L TDS for Oak Bayou, 460 mg/L TDS for Boeuf River, and 30 mg/L sulfate for Boeuf River.

Table ES.1. 303(d) listing for stream reaches in this task order.

Reach No.	Stream Name	Source	Major cause	Minor cause(s)	Priority
08050001-022	Big Bayou	Agriculture	Siltation/turbidity	Chloride	Low
08050001-018	Boeuf River	Agriculture	Siltation/turbidity	Chloride, TDS*, Sulfate*	Low
08050001-019	Boeuf River	Agriculture	Siltation/turbidity	Chloride	Low
08050002-010	Oak Bayou	Agriculture	Siltation/turbidity	Chloride, TDS	Low
08050002-003	Bayou Macon	Agriculture	Siltation/turbidity	--	Low
08050002-006	Bayou Macon	Agriculture	Siltation/turbidity	--	Low

*Note: The 2002 final 303(d) list included all of the impairments shown in this table except TDS and sulfate for the Boeuf River (reach -018), which have been added to the 2004 FINAL 303(d) list.

ADEQ historical water quality data at seven locations were analyzed for long term trends, seasonal patterns, relationships between concentration and stream flow, and relationships between turbidity and total suspended solids (TSS). These analyses showed that turbidity values tended to be highest during December through May, during which time there are larger amounts of runoff and less ground cover on cropland, both of which would allow greater amounts of erosion. This is consistent with information in the Arkansas 2002 305(b) report, which states that high turbidity values are caused by runoff from intensive row crop agriculture. For chloride, TDS, and sulfate, high concentrations tended to occur at low stream flows and during May through November, while the concentrations at high stream flows and during December through April were generally low. This is consistent with the Arkansas 2002 305(b) report, which states that elevated chlorides are probably due to discharges of irrigation water taken from aquifers.

Because turbidity cannot be expressed as a mass load, the turbidity TMDLs were expressed using TSS as a surrogate for turbidity. A basin-wide regression between TSS and turbidity was developed for each season using turbidity and TSS data from all seven water quality stations. This resulted in target TSS concentrations of 68 mg/L for summer and 52 mg/L for winter.

All thirteen TMDLs (six turbidity, four chloride, two TDS, and one sulfate) were developed using the load duration curve methodology. This method illustrates allowable loading at a wide range of stream flow conditions. The steps for applying this methodology for the TMDLs in this report were: 1) developing a flow duration curve; 2) converting the flow duration curve to load duration curves; 3) plotting observed loads with load duration curves; 4) calculating the TMDL, MOS, WLA, and LA; and 5) calculating percent reductions. Based on the analyses of the water quality data, each TMDL was developed on a seasonal basis (i.e. calculating allowable loads and percent reductions for both summer and for winter.)

For the turbidity TMDLs, the wasteload allocations for point source contributions were set to zero because TSS in these TMDLs was considered to represent inorganic suspended solids (i.e., soil and sediment particles from erosion or sediment resuspension). The suspended solids discharged by point sources in the study area are assumed to consist primarily of organic solids rather than inorganic solids. Discharges of organic suspended solids from point sources are already addressed by ADEQ through their permitting of point sources to maintain water quality standards for dissolved oxygen.

For the turbidity TMDLs, an implicit margin of safety (MOS) was incorporated through the use of conservative assumptions. The primary conservative assumption was calculating the turbidity TMDLs assuming that TSS is a conservative parameter and does not settle out of the water column. For the TDS, chloride, and sulfate TMDLs, an explicit MOS was established as 10% of the TMDL.

Because point sources were considered to have negligible effect on existing violations of water quality standards, all of the load reductions were assigned to nonpoint sources. Wasteload allocations for chloride were developed for five point source discharges based on existing effluent concentrations with zero percent reduction. The nonpoint source percent reductions needed for these TMDLs are summarized in Table ES.2.

Technical assistance for implementation of these TMDLs will be provided by the Arkansas Soil and Water Conservation Commission (ASWCC) with input from local stakeholders and other agencies. For the turbidity TMDLs, implementation should occur throughout the Boeuf River and Bayou Macon basins, rather than just in the reaches with the higher percent reductions in Table ES.2.

Table ES.2. Summary of nonpoint source percent reductions.

Reach No.	Stream Name	Parameter	Summer % Reduction	Winter % Reduction
08050001-018	Boeuf River	Turbidity	0%	73%
08050001-019	Boeuf River	Turbidity	0%	80%
08050001-022	Big Bayou	Turbidity	0%	75%
08050002-010	Oak Bayou	Turbidity	0%	45%
08050002-006	Bayou Macon	Turbidity	0%	81%
08050002-003	Bayou Macon	Turbidity	0%	68%
08050001-018	Boeuf River	Chloride	**	0%
08050001-019	Boeuf River	Chloride	**	0%
08050001-022	Big Bayou	Chloride	55%	0%
08050002-010	Oak Bayou	Chloride	62%	0%
08050001-018	Boeuf River	TDS	**	0%
08050002-010	Oak Bayou	TDS	38%	0%
08050001-018	Boeuf River	Sulfate	10%	0%

** Percent reductions that were calculated for the Boeuf River for chloride and TDS during summer were 0%, but those values are not shown in this table because they were considered to be misleading and not indicative of actual conditions.

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1.0 INTRODUCTION

This report presents total maximum daily loads (TMDLs) for siltation/turbidity, chloride, sulfate, and total dissolved solids (TDS) for six stream reaches in the Boeuf River and Bayou Macon basins in southeastern Arkansas. Each of these stream reaches was included on the 2002 Arkansas 303(d) list (ADEQ 2002a) as not supporting its designated use of aquatic life. The sources of contamination and causes of impairment from the 303(d) listing are shown in Table 1.1. The TMDLs in this report were developed in accordance with Section 303(d) of the Federal Clean Water Act and the Environmental Protection Agency's (EPA) regulations in 40 CFR 130.7.

The purpose of a TMDL is to determine the pollutant loading that a waterbody can assimilate without exceeding the water quality standard for that pollutant and to establish the load reduction that is necessary to meet the standard in a waterbody. The TMDL is the sum of the wasteload allocation (WLA), the load allocation (LA), and a margin of safety (MOS). The WLA is the load allocated to point sources of the pollutant of concern, and the LA is the load allocated to nonpoint sources (NPS). The MOS is a percentage of the TMDL that takes into account any lack of knowledge concerning the relationship between pollutant loadings and water quality.

Table 1.1. 303(d) listing for stream reaches in this task order.

Reach No.	Stream Name	Source	Major cause	Minor cause(s)	Priority
08050001-022	Big Bayou	Agriculture	Siltation/turbidity	Chloride	Low
08050001-018	Boeuf River	Agriculture	Siltation/turbidity	Chloride, TDS*, Sulfate*	Low
08050001-019	Boeuf River	Agriculture	Siltation/turbidity	Chloride	Low
08050002-010	Oak Bayou	Agriculture	Siltation/turbidity	Chloride, TDS	Low
08050002-003	Bayou Macon	Agriculture	Siltation/turbidity	--	Low
08050002-006	Bayou Macon	Agriculture	Siltation/turbidity	--	Low

*Note: The 2002 final 303(d) list included all of the impairments shown in this table except TDS and sulfate for the Boeuf River (reach -018), which have been added to the 2004 FINAL 303(d) list.

2.0 BACKGROUND INFORMATION

2.1 General Information

The study area for this project consists of the Boeuf River and Bayou Macon basins in southeastern Arkansas (see Figure A.1 in Appendix A). For both basins, the headwaters begin southeast of Pine Bluff and the general drainage pattern is southward into Louisiana. These basins are bounded on the west by the Bayou Bartholomew basin, and on the north and east by levees along the Arkansas River and Mississippi River. Both basins lie entirely within the Delta ecoregion. The Boeuf River and its tributaries (including Big Bayou, Choctaw Bayou, and Cypress Creek) form United States Geological Survey (USGS) Hydrologic Unit 08050001. Bayou Macon and its tributaries (including Oak Bayou and Clay Bayou) form USGS Hydrologic Unit 08050002. The Arkansas portion of these basins is designated by ADEQ as Planning Segment 2A. The drainage area of the Boeuf River at the Arkansas – Louisiana state line is 755 mi^2 (USGS 1979). The drainage area of Bayou Macon at the Arkansas – Louisiana state line is 518 mi^2 (USGS 1979). The two counties that cover most of the Arkansas portion of these basins are Chicot and Desha.

2.2 Topography

The topography of the Boeuf River and Bayou Macon basins is mostly level with a few areas that are slightly undulating (USDA 1967, USDA 1972, COE 2001). In general, the typical slope of most of the land in these basins is about 0.5 ft of drop per 100 ft of distance (USDA 1967, USDA 1972). Some parts of this area are poorly drained and tend to flood for at least a month or more during most years (USDA 1972). One distinct topographic feature is Macon Ridge, which starts near Eudora and extends to the southwest into Louisiana (USDA 1967).

2.3 Soils

Soil characteristics for the Bouef River and Bayou Macon basins are provided by the soil surveys for Chicot and Desha Counties (USDA 1967, USDA 1972) and by the STATSGO database, which is maintained by the USDA Natural Resources Conservation Service (NRCS). The STATSGO soils data are developed on a 1:250,000 scale and are not as detailed as the county soil surveys (prepared at a 1:24,000 scale). The NRCS is in the process of converting 1:24,000 scale data from county soil surveys into GIS format for its SSURGO database, but the SSURGO data are not yet available for much of the Boeuf River and Bayou Macon basins within Arkansas.

Figure A.2 (located in Appendix A) shows the spatial distribution of different soils based on data from the STATSGO database. The western part of the study area is covered mostly by the Perry-Portland-Rilla and the Rilla-Herbert-Perry groups of soils. The soil textures that are most common in these two groups are clay, silt loam, and silty clay. Much of the eastern part of the study area is covered by the Sharkey-Alligator-Tunica group of soils, which includes silty clay and clay soils.

2.4 Land Use

Land use data for the Arkansas portion of the Bouef River and Bayou Macon basins were obtained from the GEOSTOR database, which is maintained by the Center for Advanced Spatial Technology (CAST) at the University of Arkansas in Fayetteville. These data were based on satellite imagery from 1999. The spatial distribution of these land uses is shown on Figure A.3 (located in Appendix A) and land use percentages are shown in Table 2.1. These data indicate that over 86% of the study area consists of cropland (soybeans, cotton, rice, sorghum, and corn). The area classified as open water should include catfish ponds, which cover approximately 17,300 acres in Chicot County and 2,750 acres in Desha County (AASS 2002). The combined acreage of catfish ponds for these two counties represents about 2.4% of the study area.

Table 2.1. Land use percentages for the study area.

Land use	Percentage of study area
Soybeans	46.5%
Cotton	26.5%
Rice	11.7%
Deciduous forest	4.8%
Water	4.8%
Mixed forest	2.5%
Urban	1.6%
Sorghum/corn	1.4%
Barren	0.2%
Total	100.0%

2.5 Description of Hydrology

Average precipitation for the study area is about 50-53 inches per year (USGS 1985a). Average monthly precipitation values for Arkansas City (near McGehee) are shown on Figure 2.1; these values are highest during winter and spring and lowest during summer and early fall.

The USGS has published daily stream flow data for the Boeuf River and Bayou Macon basins at one location in Arkansas and two locations in Louisiana just south of the Arkansas state line. The locations of these flow gages are shown on Figure A.4 (located in Appendix A). Basic information and statistics for these gages are summarized in Table 2.2. Recent flow data are available for only one of these three gages (Bayou Macon at Eudora). The average monthly flows for Bayou Macon at Eudora are shown on Figure 2.2; these values are highest for January and February and lowest for September and October.

There are several canals and ditches connecting the Boeuf River and Bayou Macon. These connections allow some of the stream flow in one basin to be diverted to the other basin. The fraction of water that is diverted from one basin to the other is variable and can be affected by things such as local rainfall patterns, hydraulic resistance from debris in each stream, etc. A Corp of Engineers pumping station that is located north of Lake Chicot diverts runoff from the northern part of the Bayou Macon basin into the Mississippi River. The location of this pumping station is shown on Figure A.4. This pumping station was built in 1985 to reduce the amount of silt-laden runoff entering Lake Chicot; since then, the clarity in Lake Chicot has improved greatly. When water levels in the Mississippi River are high, up to 6500 cfs of water can be pumped through the levee into the Mississippi River; during other times, the structure allows water to flow by gravity through the levee into the Mississippi River (COE 2000).

In some instances, the flow in these basins is influenced by withdrawals of irrigation water directly from bayous or canals and by return flows of irrigation water draining from the fields. Most irrigation water, though, is withdrawn from groundwater. A database obtained from the Arkansas Soil and Water Conservation Commission (ASWCC) showed that there are over 800 surface water withdrawal sites and over 4500 groundwater withdrawal sites within the Arkansas portion of the Boeuf River and Bayou Macon basins. Approximately 98% of these withdrawal sites are for irrigation.

Table 2.2. Information for stream flow gaging stations (USGS 2002a and USGS 2004).

	Bouef River near AR/LA state line	**Bayou Macon near Kilbourne, LA**	**Bayou Macon at Eudora, AR**
USGS gage number	07367700	07369700	07369680
Descriptive location	LA Hwy 835, 2 miles south of AR/LA state line	LA Hwy 585, 3-4 miles east of Kilbourne, LA	US Hwy 65 along south edge of Eudora, AR
Period of record	Oct 1957 to Sep 1968 (continuous); Oct 1968 to Sep 2003 (scattered)	Oct 1957 to Sep 1968 (continuous); Oct 1968 to Feb 1987 (scattered)	October 1988 to current
Drainage area (mi^2)	785	504	500
Mean annual flow (cfs)	875	467	277

2.6 Irrigation

Based on 2001 data for Chicot and Desha counties, approximately 55% to 70% of the soybean acreage and 76% to 77% of the cotton acreage is irrigated (AASS 2002). Essentially 100% of the rice acreage is irrigated. Although more water is used for rice than for other crops, the average depth of irrigation water applied in Chicot and Desha counties is approximately 21 to 22 inches per year. The irrigation method used for virtually all rice and for some soybeans is flood irrigation with contour levees; furrow irrigation and a small amount of sprinkler irrigation (center pivot systems) are used on other soybean acreage and for cotton. With both flood irrigation and furrow irrigation, there is usually some water that eventually drains from the surface of the field into ditches or canals (Scott et. al. 1998). The timing of this drainage is variable, although a significant quantity of drainage occurs when rice fields are drained in late summer prior to harvest.

Figure 2.1. Mean Monthly Precipitation in Arkansas City, AR

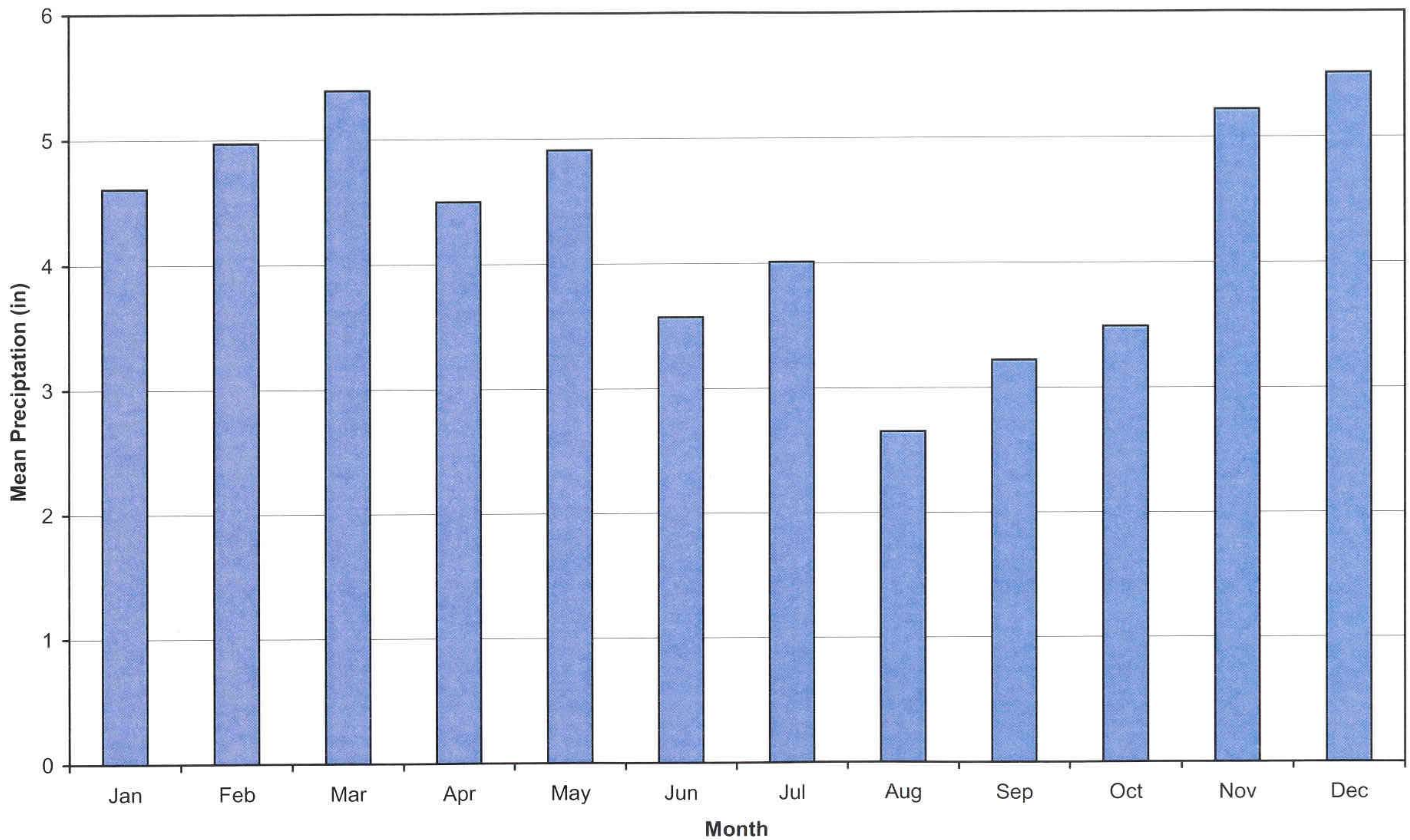
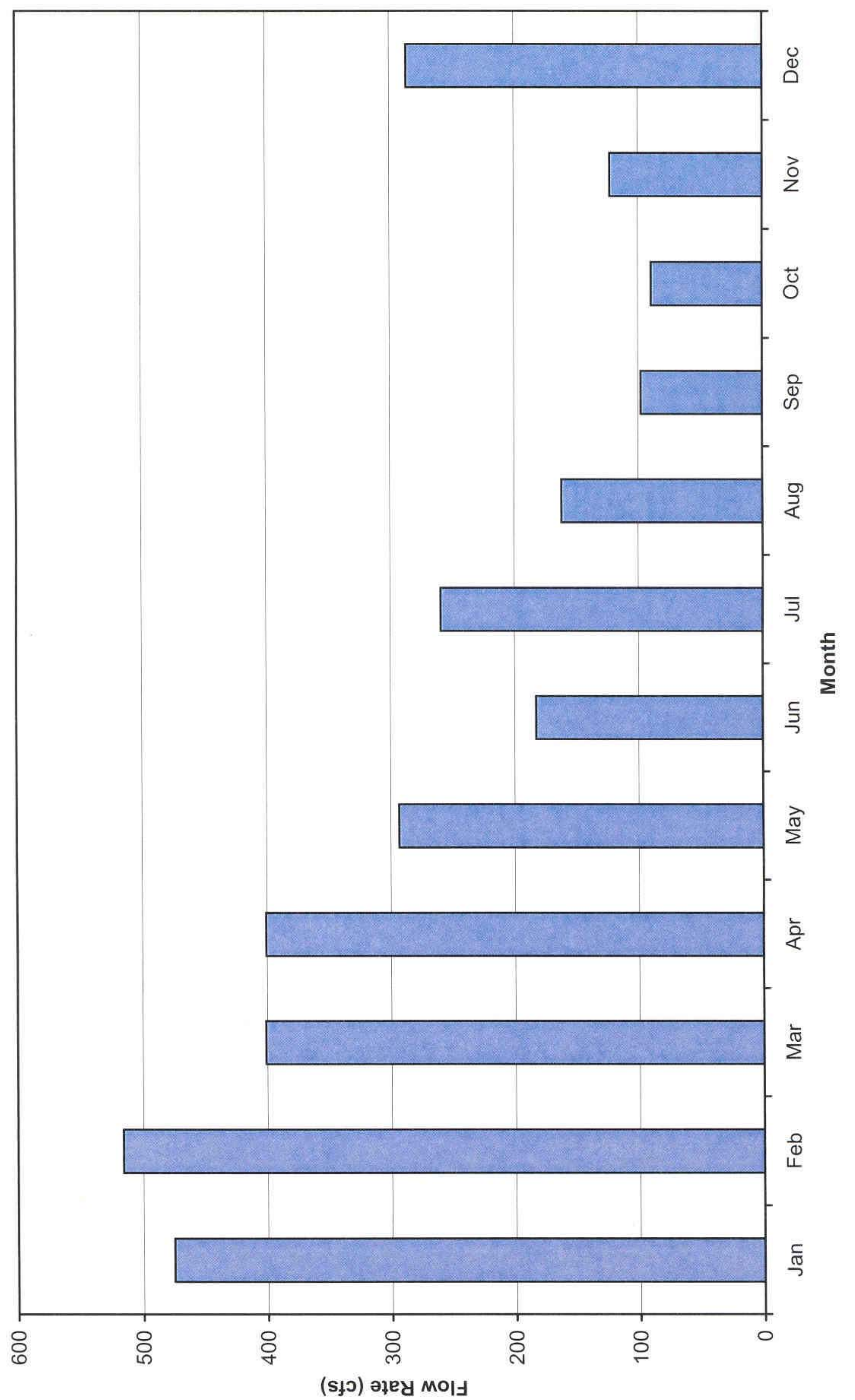


Figure 2.2. Mean Monthly Flows for Bayou Macon near Eudora, AR



2.7 Channel Network

Figure A.4 shows the stream channel network for the study area based on EPA's "Reach File 3" data. Many of the smaller stream channels have been straightened and/or deepened. In the latest 305(b) report, the discussion of water quality for planning segment 2A states that "the majority of the waters in this segment have been severely altered by channelization, ditching, and rerouting the drainage patterns" (ADEQ 2002a). Another description of this area states that "all of the major streams in the study area are either manmade canals or have been channelized. The canals and channelized streams are primarily flood control projects" (COE 2001). The Desha County soil survey states that "there is an intricate complex of drainage ditches in the county. Most of the major ones have recently been cleaned out, and the channels have been enlarged. This extensive system greatly improves the surface drainage of the county" (USDA 1972). These references support the use of the channel-altered designation for these six stream reaches listed in Table 2.3. There are also a few oxbow lakes that have been formed by changes in stream courses.

2.8 Water Quality Standards

Water quality standards for Arkansas waterbodies are listed by ecoregion in Regulation No. 2 (ADEQ 2002b). The Boeuf River and Bayou Macon basins are entirely within the Delta ecoregion. Designated uses for these basins include primary and secondary contact recreation; domestic, industrial, and agricultural water supply; and perennial Delta ecoregion fishery (for streams with at least 10 mi^2 of drainage area).

Section 2.503 of Regulation No. 2 provides both a narrative standard and a numeric standard that apply to siltation/turbidity. The general narrative standard is: "There shall be no distinctly visible increase in turbidity of receiving waters attributable to municipal, industrial, agricultural, other waste discharges or instream activities." The numeric turbidity standard for streams in the Delta ecoregion is 45 NTU for "least-altered" streams and 75 NTU for "channel-altered" streams. Regulation No. 2 does not include definitions of "least-altered" streams or "channel-altered" streams. Based on field observations and information mentioned in Section 2.7, ADEQ considers all six reaches in Table 1.1 to be channel-altered streams.

Section 2.511 of Regulation No. 2 lists numeric standards for chloride, TDS, and sulfate that are specific to Bayou Macon and the Boeuf River, as well as for other streams in the Delta ecoregion. The ecoregion standards for chloride, TDS, and sulfate are based on data from least disturbed reference streams plus allowable increases. The appropriate numeric criteria from the standards that were used for the TMDLs in this report are shown in Table 2.3.

Table 2.3. Numeric water quality standards for TMDLs in this report.

Reach No.	Stream Name	Least-altered or Channel-altered	Turbidity standard (NTU)	Chloride standard (mg/L)	TDS standard (mg/L)	Sulfate standard (mg/L)
08050001-018	Boeuf River	Channel-altered	75	90	460	30
08050001-019	Boeuf River	Channel-altered	75	90	--	--
08050001-022	Big Bayou	Channel-altered	75	48	--	--
08050002-010	Oak Bayou	Channel-altered	75	48	411	--
08050002-003	Bayou Macon	Channel-altered	75	--	--	--
08050002-006	Bayou Macon	Channel-altered	75	--	--	--

Note: Chloride, TDS, and sulfate standards are shown only for reaches that are impaired for those parameters.

As specified in EPA's regulations at 40 CFR 130.7(b)(2), applicable water quality standards include antidegradation requirements. Arkansas' antidegradation policy is listed in Sections 2.201 – 2.204 of Regulation No. 2. These sections impose the following requirements:

1) Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

2) Water quality that exceeds standards shall be maintained and protected unless allowing lower water quality is necessary to accommodate important economic or social development, although water quality must still be adequate to fully protect existing uses.

3) For outstanding state or national resource waters, those uses and water quality for which the outstanding waterbody was designated shall be protected.

4) For potential water quality impairments associated with a thermal discharge, the antidegradation policy and implementing method shall be consistent with Section 316 of the Clean Water Act.

2.9 Nonpoint Sources

Nonpoint sources of pollution in the study area are discussed in the 2002 305(b) report. For planning segment 2A (the Boeuf River and Bayou Macon basins), this report states that “the aquatic life use may be impaired due to frequent and very high turbidity and suspended solids values. It is clear that these conditions are caused by the runoff from intensive row crop agriculture which is the dominant land use within this segment” (ADEQ 2002a). Concerning nonpoint sources of chloride, the 305(b) report states that “elevated chlorides occur in lower Boeuf River and Big Bayou; this is probably from discharges of irrigation water taken from deep aquifers” (ADEQ 2002a).

2.10 Point Sources

Information for point source discharges in the Boeuf River and Bayou Macon basins (hydrologic units 08050001 and 08050002) was obtained by searching the Permit Compliance System on the EPA web site (PCS 2004). The search yielded 19 facilities with point source discharges. Search results, including flow rate and permit limits for total suspended solids (TSS), are included in Table 2.4. None of the facilities has permit limits for turbidity, chloride, sulfate, or TDS.

Locations of the permitted facilities are shown on Figure A.6 in Appendix A. Any point source discharges authorized under a general permit (rather than an individual permit) would not be revealed by this search.

2.11 Previous Water Quality Studies

There were several previous water quality studies that were particularly relevant for the TMDLs in this report. One of the studies was a water quality and biological assessment of the Boeuf River basin in Arkansas (USGS 2002b). This study included a water quality survey under relatively low flow conditions during November-December 1994 with turbidity measurements at 20 sites and chloride measurements at 24 sites. The turbidity values were above 75 NTU at 13 of the 20 sites (65%). The chloride values were above the ecoregion standard of 48 mg/L at only 4 out of 24 sites (17%); these values probably would have been higher if the survey had been conducted earlier in the year when irrigation water was draining from fields. This study also included monitoring of runoff during 11 different storms from a cotton field and from a forested area. Most of the turbidities from the cotton field runoff were between 18 NTU and 2,300 NTU, while most of the turbidities from the forested area were between 5 NTU and 71 NTU. The highest turbidities from the cotton field runoff occurred during March and April.

Another previous water quality study was a USGS investigation of saltwater in the alluvial aquifer in the Boeuf-Tensas basin (USGS 1985b). (Note: Because Bayou Macon flows into the Tensas basin in Louisiana, the Boeuf River and Bayou Macon basins are often referred to collectively as the Boeuf-Tensas basin.) This study showed that chloride concentrations in the alluvial aquifer were less than 200-300 mg/L in most of the study area except for the area between the Boeuf River and the southern part of Big Bayou, where concentrations ranged up to 1200 mg/L. The results of this study are relevant to the TMDLs in this report because the vast majority of irrigation water throughout the study area is from the alluvial aquifer. The fact that Bayou Macon is not on the 303(d) list for chloride is likely due at least in part to relatively lower chloride concentrations in the alluvial aquifer in the southeastern corner of the study area.

A third relevant study is the Southeast Arkansas Feasibility Study (SAFS), which is an ongoing project being conducted by the Vicksburg District Corps of Engineers. This is not primarily a water quality study, but the purpose of the study is to "investigate measures for providing a plan for the development, utilization, and conservation, of water and related land resources of the Boeuf-Tensas Basin, ... and coordinate with the Soil Conservation Service to jointly develop a multipurpose flood control and comprehensive agricultural water supply plan, including a system of distributary canals for Chicot, Desha, Drew, Lincoln, and Jefferson Counties in Southeast Arkansas" (COE 2001). The SAFS project was initiated in response to problems with flooding and with agricultural water supply (i.e., rapidly declining groundwater levels). In addition to promoting agricultural water conservation through efficient use of water, this project will likely result in surface water sources of irrigation water being developed in the future. Using less groundwater and more surface water for irrigation would likely reduce the chloride concentrations in streams throughout this area. As part of the SAFS project, the Boeuf-Tensas Regional Irrigation Water Distribution District has been created to manage regional distribution of irrigation water in the future.

The fourth previous study is a Wetland Planning Area (WPA) report for the Boeuf-Tensas basin in Arkansas. Currently, the report for this study is not yet finished, but it is anticipated to be available soon.

Table 2.4. Inventory of point source dischargers.

NPDES permit number	Facility name	Flow rate (MGD)	Discharge path to RF-1 Reach	RF-1 reach that discharge flows into	RF-1 reach on 303d list for chloride, sulfate, or TDS?
AR0021679	Gould City Of	0.15	Trib Kerch Can Cypress Ck	08050001-020	No
AR0022071	McGehee City Of	0.6		08050001-022	Chloride
AR0022250	Dermott City Of-South Pond	1.2		08050001-022	Chloride
AR0033707	Tillar City Of	0.09	Can #18 Macon Bu Boeuf Rv	08050001-019	Chloride
AR0033987	Dumas City Of	1.37	Can #19 Bu Macon	08050001-020	No
AR0039381	Grady City Of	0.07	Can #19 Bu Macon	08050001-020	No
AR0041297	Montrose City Of	0.1	Wards Bu Trib	08050001-022	Chloride
AR0042838	Farmland Industries Inc-South	0.38	Bu Macon	08050002-003	No
AR0046507	AR Hwy Dept-McGehee Hq	0.0005	Dit Can#18 Macon Bu Macon L Caneybu	08050001-019	Chloride
ARG340056	Delta Farmers Assn-Grady		Choctaw Bu Walnut Lk	08050001-021	No
ARG640119	Eudora City Of-PWTP	0.08	Dit Caney Bu Ouachita Rv 2a	08050002-003	No
AR0021610	Watson City Of	0.09	Red Fork Bu	08050002-008	No
AR0021849	Lake Village City Of	0.82	Ltl Lake Bu Bu Macon Boeuf Rv	08050002-006	No
AR0033839	Eudora City Of	0.6	Bu Macon	08050002-003	No
AR0037125	Mitchellville City Of	0.06	Can #19 Cypress Ck Amos Bu Boggy Bu	08050001-020	No
AR0039039	Delta Special School District	0.01	Dit Boggy Bu Clay Bu	08050002-009	No
AR0040827	AR Dept Of Correction-Cummins	0.8	Can #19	08050001-020	No
AR0050008	Chicot County Park	0.013	Lk Chicot Ditch Bu Macon Bayou ...	08050002-005	No
AR0050091	Chicot County-Ditch Bayou Boat	0.0005	Ditch Bu, Bu Macon	08050002-004	No

3.0 EXISTING WATER QUALITY FOR TURBIDITY AND TSS

3.1 General Description of Data

Turbidity and total suspended solids (TSS) data have been collected by ADEQ at 7 sites along the 6 stream reaches that are impaired for siltation/turbidity within the study area. Locations of these sampling sites are shown on Figure A.7 (located in Appendix A). Tables 3.1 and 3.2 show summaries of these data by season, including percentages of values above water quality standards. TSS data are included in this summary because TSS is needed as a surrogate parameter for expressing the siltation/turbidity TMDLs. Time series plots of data for the entire period at each station are shown on Figures B.1 – B.7 for turbidity and Figures B.8 – B.14 for TSS (located in Appendix B). These data were obtained from the ADEQ and STORET web sites (ADEQ 2004, STORET 2004).

3.2 Seasonal Patterns

The seasons in Tables 3.1 and 3.2 were defined based on visual examination of plots of turbidity versus day of the year (Figures C.1 – C.7; located in Appendix C). Even though the water quality standard for turbidity does not vary seasonally, the data were evaluated by seasons to show how existing water quality varies seasonally and to provide additional insight concerning causes of water quality problems. At all 7 stations, turbidity values tend to be higher during winter (December through May) and lower during summer (June through November). The higher turbidities in winter may be due to larger amounts of runoff and less ground cover on cropland, both of which would allow greater amounts of erosion. The seasonal plots of TSS (Figures C.8 – C.14) show a similar but less consistent seasonal pattern.

3.3 Relationships Between Turbidity and Flow

Plots of turbidity versus stream flow were also developed to examine any correlation between these two parameters (Figures D.1 – D.7; located in Appendix D). These plots show little or no correlation between turbidity and stream flow. This lack of correlation between turbidity and stream flow was not considered unusual because similar results occurred for the Bayou Bartholomew basin (which is adjacent to the Boeuf River basin) (FTN 2003).

3.4 Relationships Between TSS and Turbidity

Plots of TSS versus turbidity for each station (Figures D.8-D.14) show a noticeable correlation, with higher turbidity levels tending to correspond with higher TSS concentrations. Linear regression was performed on the natural logarithms of turbidity and TSS; the results of these regressions are summarized in Table 3.3. The regressions were performed using the natural logarithms of the data (rather than the raw data values) because most data such as turbidity and TSS fit a lognormal distribution better than a normal distribution.

Table 3.1. Summary of turbidity data.

Station	Station description	Period of record	December – May				June - November			
			No. of values	Median value (NTU)	No. of values above 75 NTU	% of values above 75 NTU	No. of values	Median value (NTU)	No. of values above 75 NTU	% of values above 75 NTU
OUA0015A	Boeuf River near AR-LA State Line	4/4/77-2/17/04	143	205	130	91%	140	21	41	29%
UWBFR01	Boeuf River at Hwy 278, 4 mi W of Chicot	6/6/94-9/10/01	7	230	6	86%	8	27	2	25%
OUA0032	Big Bayou near Jerome	4/4/77-9/10/01	32	185	30	94%	35	35	7	20%
UWBGB01	Big Bayou at Hwy 278, 5 mi E of Portland	6/6/94-9/10/01	7	170	6	86%	8	33	0	0%
OUA0179	Oak Bayou south of Pea Ridge	11/7/00-9/11/01	3	260	2	67%	3	31	0	0%
UWBYM01	Bayou Macon at Hwy 65 near Eudora	6/6/94-9/10/01	7	100	5	71%	9	35	0	0%
UWBYM02	Bayou Macon 5 mi above McMillan Corner	6/6/94-1/22/01	5	380	5	100%	7	18	2	29%

Table 3.2. Summary of TSS data.

Station	Description	Period of record	December - May				June - November			
			No. of values	Min.	Median	Max.	No. of values	Min.	Median	Max.
OUA0015A	Boeuf River near AR-LA State Line	12/14/71-2/17/04	162	7	118	1396	167	7	31	479
UWBFR01	Boeuf River at Hwy 278, 4 mi W of Chicot	6/6/94-9/10/01	7	30	150	368	8	23	36	614
OUA0032	Big Bayou near Jerome	9/9/72-9/10/01	42	24	96	1810	60	4	44	1215
UWBGB01	Big Bayou at Hwy 278, 5 mi E of Portland	6/6/94- 9/10/01	7	37	59	526	8	18	36	49
OUA0179	Oak Bayou south of Pea Ridge	11/7/00-9/11/01	3	46	100	130	3	21	43	67
UWBYM01	Bayou Macon at Hwy 65 near Eudora	6/6/94-9/10/01	7	30	109	814	9	9	64	94
UWBYM02	Bayou Macon 5 mi above McMillan Corner	6/6/94-1/2201	5	28	50	244	7	2	7	203

Table 3.3. Results of regressions between TSS and turbidity for each station.

Sampling station	Regression equation	Number of data	R^2	Significance level (P value)
OUA0015A	ln TSS = 0.7110 * ln Turbidity + 1.035	268	0.80	5.3×10^{-95}
UWBFR01	ln TSS = 0.7026 * ln Turbidity + 1.088	14	0.79	2.0×10^{-5}
OUA0032	ln TSS = 0.7988 * ln Turbidity + 0.6446	49	0.73	3.9×10^{-15}
UWBGB01	ln TSS = 0.7282 * ln Turbidity + 0.9721	15	0.80	6.4×10^{-6}
OUA0179	ln TSS = 0.4965 * ln Turbidity + 2.028	6	0.86	7.5×10^{-3}
UWBYM01	ln TSS = 0.7177 * ln Turbidity + 1.443	16	0.61	3.5×10^{-4}
UWBYM02	ln TSS = 0.7529 * ln Turbidity – 0.0383	12	0.84	2.7×10^{-5}

The strength of the linear relationship is measured by the coefficient of determination (R^2) calculated during the regression analysis (Zar 1996). The R^2 value is the percentage of the total variation in ln TSS that is explained or accounted for by the fitted regression (ln turbidity). For example, for station OUA0015A, 80% of the variation in TSS is accounted for by turbidity and the remaining 20% of variation in TSS is unexplained. The unexplained portion is attributed to factors other than turbidity. The correlation between TSS and turbidity was considered to be good, with R^2 values ranging from 0.61 to 0.86. These values are higher than R^2 values for turbidity and TSS from other approved TMDLs in eastern Arkansas (FTN 2001, FTN 2003) and northeastern Louisiana (EPA 2002).

The statistical significance of each regression was evaluated by computing the “P value” for the slope for each regression. The P value is essentially the probability that the slope of the regression line is really zero. Thus, a low P value indicates that a non-zero slope calculated from the regression analysis is statistically significant. For all 7 stations, the P value was less than 0.01, which is considered acceptable. It should be noted that the station that had the highest R^2 value (OUA0179) also had the largest (i.e., least significant) P value due to the small number of data points. Also, the small number of data points caused the slope of the regression at station OUA0179 (0.4965) to be considerably different than the slopes for the other stations (0.7026 to 0.7988).

The data for all stations in the study area were combined to develop two seasonal regression equations shown in Table 3.4 and Figures D.15 and D.16. This conclusion is based on similarities in land use in the study area and most of the individual station regressions being close to the same slope. Several of the stations had relatively few readings and combining them lends weight to the result. The data shows a marked seasonality as shown in Appendix C. The small data sets for some stations would have produced weak regressions for two seasons. An additional benefit of combining the data is a single regression for each season will be used throughout the study area.

Table 3.4. Results of basin wide regressions between TSS and turbidity.

Season	Regression equation	Number of data	R^2	Significance level (P value)
Dec – May	ln TSS = 0.806 * ln Turbidity + 0.467	196	0.64	1.05×10^{-44}
Jun – Nov	ln TSS = 0.771 * ln Turbidity + 0.893	200	0.77	1.78×10^{-64}

4.0 EXISTING WATER QUALITY FOR CHLORIDE, TDS, AND SULFATE

4.1 General Description of Data

Chloride, total dissolved solids (TDS), and sulfate data have been collected by ADEQ at 5 sites along the 4 stream reaches that are impaired for chloride, sulfate, or TDS within the study area. Locations of these sampling sites are shown on Figure A.7. Table 4.1 shows summaries of these data by season, including percentages of values above water quality standards. Time series plots of data for the entire period at each station are shown on Figures E.1 – E.5 for chloride, Figures E.6 – E.7 for TDS, and Figure E.8 for sulfate (located in Appendix E). Chloride, TDS, and sulfate data are shown here only for the stations on stream reaches that are impaired for each parameter. These data were obtained from the ADEQ and STORET web sites (ADEQ 2004, STORET 2004).

4.2 Seasonal Patterns

The seasons in Table 4.1 were defined based on visual examination of plots of chloride, TDS, and sulfate versus day of the year (Figures F.1 – F.8; located in Appendix F). Even though the water quality standards for chloride, TDS, and sulfate do not vary seasonally, the data were evaluated by seasons to show how existing water quality varies seasonally and to provide additional insight concerning causes of water quality problems. These plots show that chloride, TDS, and sulfate values tend to be higher during summer (May through November) and lower during winter (December through April). This seasonal pattern was also shown by the higher percentages of values exceeding standards during summer (Table 4.1). Based on information discussed in Section 2.0, the higher concentrations of chloride, TDS, and sulfate in summer are assumed to be due to application of irrigation water that is high in dissolved minerals concentrations.

4.3 Relationships Between Concentration and Flow

Plots of chloride, TDS, and sulfate versus stream flow were also developed to examine any correlation between concentration and flow (Figures G.1 – G.8; located in Appendix G). These plots show that the highest concentrations usually occur during relatively low flow periods and high flow periods usually have low concentrations. This pattern is consistent with the assumption that irrigation water is the primary source of dissolved minerals in the impaired reaches. Because high flow periods usually have low concentrations, storm runoff from the watershed does not appear to be the cause of water quality standards violations for chloride, sulfate, or TDS.

Table 4.1. Summary of chloride and TDS data.

Station	Station description	Period of record	Parameter	Standard (mg/L)	December - April				May - November			
					No. of values	Median (mg/L)	No. of values above standard	% of values above standard	No. of values	Median (mg/L)	No. of values above standard	% of values above standard
OUA0015A	Boeuf River near AR-LA State Line	12/14/71 – 2/17/04	Chloride	90	154	15	1	1%	327	33	61	19%
			TDS	460	81	218	0	0%	123	326	25	20%
			Sulfate	30	135	11	7	5%	188	26	73	39%
UWBFR01	Boeuf River at Hwy 278, 4 mi W of Chicot	6/6/94 – 9/10/01	Chloride	90	5	17	0	0%	10	58	3	30%
OUA0032	Big Bayou near Jerome, AR	6/11/74 – 9/10/01	Chloride	48	38	14	1	3%	53	49	29	55%
UWBGB01	Big Bayou at Hwy 278, 5 mi E of Portland	6/6/94 – 9/10/01	Chloride	48	5	19	1	20%	10	91	8	80%
OUA0179	Oak Bayou south of Pea Ridge	11/7/00 – 9/11/01	Chloride	48	2	8	0	0%	4	120	4	100%
			TDS	411	2	219	0	0%	4	532	4	100%

5.0 TMDL DEVELOPMENT

5.1 Seasonality and Critical Conditions

EPA's regulations at 40 CFR 130.7 require the determination of TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. Also, both Section 303(d) of the Clean Water Act and regulations at 40 CFR 130.7 require TMDLs to consider seasonal variations for meeting water quality standards. Therefore, the historical data and analyses discussed in Sections 3.0 and 4.0 were used to evaluate whether there were certain flow conditions or certain periods of the year that could be used to characterize critical conditions.

For the turbidity TMDLs, no significant relationships were found between turbidity and stream flow, but the seasonal plots of turbidity (Figures C.1 – C.7) showed higher values during the winter months (December through May) compared to the summer months (June through November). Therefore, the turbidity TMDLs were developed based on these seasons, but not for a specific flow condition. The methodology used to develop these TMDLs (load duration curve) addresses a wide range of flow conditions.

For chloride, TDS, and sulfate, the high concentrations tended to occur at low stream flows and during the summer months (May through November), while the concentrations at high stream flows and during winter months (December through April) were generally low. Therefore, the chloride, TDS, and sulfate TMDLs were developed using these seasons. The methodology used to develop these TMDLs (load duration curve) addresses a wide range of flow conditions.

5.2 Water Quality Targets

Turbidity is an expression of the optical properties in a water sample that cause light to be scattered or absorbed and may be caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and plankton and other microscopic organisms (Standard Methods 1999). Turbidity cannot be expressed as a load as preferred for TMDLs. To achieve a load based value, turbidity is often correlated with a surrogate parameter such as TSS that may be expressed as a load. For the turbidity TMDLs in this report, the basin wide relationships between turbidity and TSS presented in Table 3.4 were used to develop target TSS concentrations (i.e., numeric endpoints for the TMDLs). These relationships and the resulting target TSS concentrations are shown in Table 5.1.

Table 5.1. Target TSS concentrations for turbidity TMDLs.

Season	Regression equation	Turbidity standard	Target TSS concentration
Winter (Dec – May)	ln TSS = 0.806 * ln Turbidity + 0.467	75 NTU	52 mg/L
Summer (June – Nov)	ln TSS = 0.771 * ln Turbidity + 0.893	75 NTU	68 mg/L

The water quality targets for chloride and TDS were simply the water quality standards shown in Table 2.3 (90 mg/L chloride for Boeuf River, 48 mg/L chloride for other streams, 411 mg/L TDS for Oak Bayou, 460 mg/L TDS for Boeuf River, and 30 mg/L sulfate for Boeuf River). Chloride, TDS, and sulfate can easily be expressed as mass, so there was no need to use surrogate parameters.

5.3 Methodology for TMDL Calculations

The methodology used for all of the TMDLs in the report is the load duration curve. Because loading capacity varies as a function of the flow present in the stream, these TMDLs represent a continuum of desired loads over all flow conditions, rather than fixed at a single value. The basic elements of this procedure are documented on the Kansas Department of Health and Environment web site (KDHE 2003). This method was used to illustrate allowable loading at a wide range of flows. The steps for how this methodology was applied for the TMDLs in this report can be summarized as follows:

1. Develop a flow duration curve (Section 5.4)
2. Convert the flow duration curve to load duration curves (Section 5.5)
3. Plot observed loads with load duration curves (Section 5.6)
4. Calculate TMDL, MOS, WLA, and LA (Section 5.7)
5. Calculate percent reductions required to meet assessment criteria (Section 5.10)

5.4 Flow Duration Curve

A flow per unit area duration curve was developed for each season for the whole study area. Daily streamflow measurements from Bayou Macon at Eudora (USGS gage number 07369680) were separated into summer and winter data sets and each data set was sorted in increasing order and the percentile ranking of each flow was calculated. The data from the Eudora gage were used because the load duration methodology requires that the same flow data be used for developing the flow duration as for calculating observed loads from sampling data (the Eudora gage was the only flow gage with data during the years that water quality sampling occurred).

Because flows at the Eudora gage represented only a portion of the total flow in the watershed, the flows were adjusted. The only time period when flows were published for both Boeuf River and Bayou Macon was 1957-68, which is the period of record for continuous flows for Boeuf River near AR-LA state line (USGS gage number 07367700) and Bayou Macon near Kilbourne, LA (USGS gage number 07369700). Based on the mean annual flows from these two USGS gages (07367700 and 07369700), Bayou Macon represented approximately 34.8% of the total flow from both streams. Therefore, the flows for Bayou Macon at Eudora (07369680) were divided by 34.8%. In order to develop a flow duration curve to be used for different stream reaches with different drainage areas, the adjusted flows for Bayou Macon at Eudora were then divided by 1289 mi^2, which is the combined drainage area for the two flow gages near the state line (Boeuf River near AR-LA state line and Bayou Macon near Kilbourne). For each season, these adjusted flows per unit area were then plotted against their corresponding percent exceedances to yield the flow duration curves shown in Figures H.1 and I.1 (in Appendices H and I) for summer and winter, respectively.

5.5 Load Duration Curves

For each season and for each TMDL parameter (TSS, chloride, TDS, and sulfates), the adjusted flows per unit area from the flow duration curves were multiplied by the appropriate target concentration (from Section 5.2) to make an allowable load per unit area duration curve. Each load duration curve is a plot of tons per day per mi^2 of drainage area versus the percent exceedances from the flow duration curves. The eight sets of load duration curves are presented in the following appendices:

APPENDIX H:	load duration curve for TSS during summer
APPENDIX I:	load duration curve for TSS during winter
APPENDIX J:	load duration curve for chloride during summer
APPENDIX K:	load duration curve for chloride during winter
APPENDIX L:	load duration curve for TDS during summer
APPENDIX M:	load duration curve for TDS during winter
APPENDIX N:	load duration curve for sulfate during summer
APPENDIX O:	load duration curve for sulfate during winter

The calculations for these load duration curves are shown in Tables H.1, I.1, J.1, K.1, L.1, M.1, N.1, and O.1. Because the load duration curves were expressed per unit of drainage area, each curve was applicable at all sampling stations and for all stream reaches.

The load duration curve is beneficial when analyzing monitoring data with its corresponding flow information plotted as a load. This allows the monitoring data to be placed in relation to its place in the flow continuum. Assumptions of the probable source or sources of the impairment can then be made from the plotted data.

The load duration curve shows the calculation of the TMDL at any flow rather than at a single critical flow. The official TMDL number is reported as a single number, but the curve is provided to demonstrate the value of the acceptable load at any flow. This will allow analysis of load cases in the future for different flow regimes.

5.6 Observed Loads

For each season and each sampling station, observed loads were calculated by multiplying each observed concentration of TSS, chloride, TDS, or sulfate by the adjusted flow per unit area on the sampling day (calculations to obtain adjusted flows per unit area were discussed in Section 5.4). These observed loads were then plotted versus the percent exceedances of the flow per unit area on the sampling day and placed on the same plot as the load duration curve. These plots are shown in the appendices of this report as follows:

Figures H.2 – H.8:	plots of loads for TSS during summer
Figures I.2 – I.8:	plots of loads for TSS during winter
Figures J.2 – J.6:	plots of loads for chloride during summer
Figures K.2 – K.6:	plots of loads for chloride during winter
Figures L.2 – L.3:	plots of loads for TDS during summer
Figures M.2 – M.3:	plots of loads for TDS during winter

Figure N.2: plot of loads for sulfate during summer
Figure O.2: plot of loads for sulfate during winter

These plots provide visual comparisons between observed and allowable loads under different flow conditions. Observed loads that are plotted above the load duration curve (identified as "TMDL" curve in the legend) represent conditions where observed water quality concentrations exceed the target concentrations. Observed loads below the load duration curve represent conditions where observed water quality concentrations were less than target concentrations (i.e., not violating water quality standards).

The observed loads of TSS that occurred during the highest 10% of stream flows are not shown on Figures H.2 – H.8 and Figures I.2 – I.8. These loads were not included in the TMDL calculations because it is not considered feasible to control TSS during extremely high flows. This exclusion of data during the highest 10% of stream flows has been widely used for load duration curves throughout the U.S.

5.7 TMDL and MOS

Each TMDL was calculated as the area under the load duration curve. Because the load duration curves were expressed in mass per unit drainage area, the area under the curve was multiplied by the estimated area draining directly to that reach (i.e., excluding areas draining into upstream reaches). Due to the many hydraulic connections between different streams, delineation of drainage areas required some assumptions concerning direction of flow in connecting channels. For each turbidity TMDL, the allowable load during the highest 10% of stream flows was excluded (i.e., the TMDL was calculated as the area under the load duration curve between the 10% flow exceedance and the 100% flow exceedance). As mentioned in Section 5.6, this exclusion of loads for the highest 10% of stream flows has been widely used for load duration curves throughout the U.S. because it is not considered feasible to control TSS during extremely high flows.

Both Section 303(d) of the Clean Water Act and regulations at 40 CFR 130.7 require TMDLs to include a MOS to account for uncertainty in available data or in the actual effect that controls will have on the loading reductions and receiving water quality. The MOS may be expressed explicitly as unallocated assimilative capacity or implicitly through conservative assumptions used in establishing the TMDL. For the turbidity TMDLs, an implicit MOS was incorporated through the use of conservative assumptions. The primary conservative assumption was calculating the turbidity TMDLs assuming that TSS is a conservative parameter and does not settle out of the water column. For the TDS,chloride, and sulfate TMDLs, an explicit MOS was established as 10% of the TMDL .

5.8 Point Source Loads

For the turbidity TMDLs, the WLAs for the point sources were set to zero because the surrogate being used for turbidity (TSS) is considered to represent inorganic suspended solids (i.e., soil and sediment particles from erosion or sediment resuspension). The suspended solids discharged by point sources in the Bayou Macon and Boeuf River basins are assumed to consist primarily of organic solids rather than inorganic solids. Discharges of organic suspended solids from point sources are already addressed by ADEQ through their permitting of point sources to maintain water quality standards for DO. The WLAs to support the six turbidity TMDLs will not require any changes to the permits concerning inorganic suspended solids. It then follows that future growth for these permits or new permits wouldn't be restricted by these turbidity TMDLs.

For the chloride TMDLs, the WLAs for the point sources were calculated by determining the combined design flow of all of the point sources that discharge to that reach and multiplying that total flow times an assumed effluent chloride concentration of 60 mg/L. This assumed chloride concentration was based on the measured value in the NPDES permit application for the City of Dermott wastewater treatment plant; no other effluent concentrations of chloride were found among NPDES permit applications for dischargers in the study area. The value of 60 mg/L of chloride was consistent with literature values for medium strength domestic wastewater (Metcalf & Eddy 1991). The WLAs for the TDS and sulfate TMDLs were zero because no point sources discharge into Oak Bayou (reach 08050002-010) or the Boeuf River (reach 08050001-018). The five WLAs for individual point sources are summarized in Appendix P. WLAs are not needed for the other 14 point sources listed in Table 2.4 because they do not discharge to a reach that is impaired due to chloride, sulfate, or TDS.

Future growth for the point sources discharging to the Boeuf River (reach 08050001-019) is not limited by these TMDLs as long as the effluent concentrations of chloride are less than the water quality standard of 90 mg/L. As demonstrated by the load duration curve, the assimilative capacity for chloride in the stream increases as the total amount of flow in the stream increases. Therefore, as the flow from point source discharges increases, the allowable chloride loading for point sources also increases. For the point sources discharging to the Boeuf River (reach 08050001-019), no portion of the TMDL was explicitly designated as future growth.

Future growth for the point sources discharging to Big Bayou (reach 08050001-022) was calculated by allowing an arbitrary 50% increase in the current design flow rates with no change in the effluent concentration of 60 mg/L chloride. Because the assumed effluent concentration was greater than the water quality standard of 48 mg/L chloride for Big Bayou, the portion of the increase that was above the standard (12 mg/L multiplied by 50% of current design flows) was explicitly designated as future growth.

Although the chloride,TDS, and sulfate TMDLs for other reaches do not include any WLAs or future growth, new point sources could begin discharging to those reaches and grow without being limited by these TMDLs as long as their discharge concentrations were at or below the water quality standards for the parameter(s) for which the reach was impaired.

5.9 Nonpoint Source Loads

For the turbidity TMDLs, the LAs for nonpoint sources were set equal to the TMDLs because the WLAs were zero and the MOS was implicit. For the chloride, sulfate, and TDS TMDLs, each LA was calculated as the TMDL minus the sum of the WLA, the MOS, and future growth.

Calculations for the TMDLs, WLAs, and LAs are shown in the appendices of this report as follows:

Tables H.2 – H.8:	calculations for TSS during summer
Tables I.2 – I.8:	calculations for TSS during winter
Tables J.2 – J.6:	calculations for chloride during summer

Tables K.2 – K.6:	calculations for chloride during winter
Table L.2 – L.3:	calculations for TDS during summer
Table M.2 – M.3:	calculations for TDS during winter
Table N.2:	calculations for sulfate during summer
Table O.2:	calculations for sulfate during winter

5.10 Percent Reductions

In addition to calculating allowable loads, estimates were made for percent reductions of nonpoint source loads that would be necessary for each impaired reach to meet water quality standards. Each load percent reduction was calculated from the following equation:

Load percent reduction = 100% × (Existing load – (TMDL – MOS)) / Existing load

These load percent reductions are shown along with the results of the TMDL calculations in Tables 5.2 – 5.9.

In addition to calculating percent reductions based on average loads as shown above, the observed loads were also analyzed to see what percent reductions would be needed for the observed data to meet ADEQ's assessment criteria for supporting designated uses (ADEQ 2002a). The observed loads of TSS, chloride, TDS, and sulfate at each sampling station and for each season were reduced by certain percentages until the number of loads above the load duration curve (i.e., the number of exceedances) was within the allowable number of exceedances for supporting designated uses. For TSS, the allowable numbers of loads above the load duration curve were calculated as the number of observed values times 25% (and then rounded up to the next whole number). For chloride, TDS, and sulfate, the allowable numbers of loads above the load duration curve were calculated as the number of observed values times 10% (and then rounded up to the next whole number). The results of these percent reduction calculations are shown in the same tables as for the TMDL, WLA, and LA calculations (tables are listed by parameter and season in Section 5.9). These percent reductions based on meeting the assessment criteria were provided only as supplemental information; the load percent reductions are the values that should be used for implementation of these TMDLs.

Table 5.2. Summary of turbidity TMDLs for June through November (summer).

Reach ID	Stream name	Loads (tons/day of TSS)					Percent reduction needed
		WLA	LA	MOS	Future growth	TMDL	
08050001-018	Boeuf River	0	6.39	implicit	0	6.39	0%
08050001-019	Boeuf River	0	6.27	implicit	0	6.27	0%
08050001-022	Big Bayou	0	6.72	implicit	0	6.72	0%
08050002-010	Oak Bayou	0	4.84	implicit	0	4.84	0%
08050002-006	Bayou Macon	0	2.58	implicit	0	2.58	0%
08050002-003	Bayou Macon	0	3.13	implicit	0	3.13	0%

Table 5.3. Summary of turbidity TMDLs for December through May (winter).

Reach ID	Stream name	Loads (tons/day of TSS)					Percent reduction needed
		WLA	LA	MOS	Future growth	TMDL	
08050001-018	Boeuf River	0	10.93	implicit	0	10.93	73%
08050001-019	Boeuf River	0	10.73	implicit	0	10.73	80%
08050001-022	Big Bayou	0	11.50	implicit	0	11.50	75%*
08050002-010	Oak Bayou	0	8.29	implicit	0	8.29	45%
08050002-006	Bayou Macon	0	4.41	implicit	0	4.41	81%
08050002-003	Bayou Macon	0	5.36	implicit	0	5.36	68%

* Percent reduction for Big Bayou was based on calculations for station OUA0032 rather than station UWBGB01 because data from station OUA0032 yielded a higher percent reduction.

Table 5.4. Summary of chloride TMDLs for May through November (summer).

Reach ID	Stream name	Loads (tons/day of chloride)					Percent reduction needed
		WLA	LA	MOS	Future growth	TMDL	
08050001-018	Boeuf River	0	14.55	1.62	0	16.17	**
08050001-019	Boeuf River	0.02	14.27	1.59	0	15.88	**
08050001-022	Big Bayou	0.48	7.63	0.91	0.05	9.07	55%*
08050002-010	Oak Bayou	0	5.89	0.65	0	6.54	62%

* Percent reduction for Big Bayou was based on calculations for station OUA0032 rather than station UWBGB01 because data from station OUA0032 yielded a higher percent reduction.

** Due to the distribution of the observed data and flow conditions during which exceedances occurred, the percent reductions for the Boeuf River for chloride during summer were 0%. The value of 0% is not shown in this table because it was considered to be misleading and not indicative of actual conditions.

Table 5.5. Summary of chloride TMDLs for December through April (winter).

Reach ID	Stream name	Loads (tons/day of chloride)					Percent reduction needed
		WLA	LA	MOS	Future growth	TMDL	
08050001-018	Boeuf River	0	36.12	4.01	0	40.13	0%
08050001-019	Boeuf River	0.02	35.44	3.94	0	39.40	0%
08050001-022	Big Bayou	0.48	19.73	2.25	0.05	22.51	0%
08050002-010	Oak Bayou	0	14.61	1.62	0	16.23	0%

Table 5.6. Summary of TDS TMDLs for May through November (summer).

Reach ID	Stream name	Loads (tons/day of TDS)					Percent reduction needed
		WLA	LA	MOS	Future growth	TMDL	
08050001-018	Boeuf River	0	74.39	8.27	0	82.66	**
08050002-010	Oak Bayou	0	50.38	5.60	0	55.98	38%

** Due to the distribution of the observed data and the flow conditions during which exceedances occurred, the percent reduction for the Beouf River for TDS during summer was 0%. The value of 0% is not shown in this table because it was considered to be misleading and not indicative of actual conditions.

Table 5.7. Summary of TDS TMDLs for December through April (winter).

Reach ID	Stream name	Loads (tons/day of TDS)					Percent reduction needed
		WLA	LA	MOS	Future growth	TMDL	
08050001-018	Boeuf River	0	184.61	20.51	0	205.12	0%
08050002-010	Oak Bayou	0	125.04	13.89	0	138.93	0%

Table 5.8. Summary of sulfate TMDL for May through November (summer).

Reach ID	Stream name	Loads (tons/day of Sulfates)					Percent reduction needed
		WLA	LA	MOS	Future growth	TMDL	
08050001-018	Boeuf River	0	4.85	0.54	0	5.39	10%

Table 5.9. Summary of sulfate TMDL for December through April (winter).

Reach ID	Stream name	Loads (tons/day of Sulfates)					Percent reduction needed
		WLA	LA	MOS	Future growth	TMDL	
08050001-018	Boeuf River	0	12.04	1.34	0	13.38	0%

5.11 Future Growth

Strategies for future growth for specific reaches and pollutants were discussed in Section 5.8. These strategies were not formulated on every possible change that could happen within a reach. The most obvious thing that cannot be predicted is the exact location of a new load to the reach. For situations outside the guidelines of Section 5.8, the load duration curves for the reach-pollutant combination can be used in conjunction with the assumptions and approach in this document to determine if a proposed change is bounded by the acceptable load shown on the load duration curve. This will guide the management of the segment with the goal of meeting water quality standards as the point and nonpoint source loads change.

6.0 OTHER RELEVANT INFORMATION

6.1 Monitoring

In accordance with Section 106 of the federal Clean Water Act and under its own authority, ADEQ has established a comprehensive program for monitoring the quality of the State's surface waters. ADEQ collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for long term trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters.

6.2 Reasonable Assurances and Implementation

For some of the chloride TMDLs, significant nonpoint source reductions are required while point source loads are not being reduced and are even allowed a small amount of future growth. Therefore, it is required to provide reasonable assurances that reductions of nonpoint source loads of chloride are likely to occur.

As discussed previously in this report, irrigation with groundwater is believed to be the primary cause of exceedances of water quality standards for chloride. Reducing the use of groundwater for irrigation is one of the primary goals of the Southeast Arkansas Feasibility Study (SAFS), which is being conducted by the Vicksburg district Corps of Engineers, along with ASWCC and other partner agencies. This study was prompted by rapidly declining groundwater levels, which is a serious concern among state and federal agencies as well as farmers in eastern Arkansas. This project includes promoting agricultural water conservation, such as installing tailwater recovery systems to reduce runoff of irrigation water, and building reservoirs to store storm runoff during wet seasons and use it later for irrigation water. Results of this project will also likely include development of one or more major surface water sources of irrigation water. Options for major surface water sources that are being evaluated by the Corps of Engineers include diverting water from the Arkansas River into a network of canals for distribution throughout the Boeuf River and Bayou Macon basins. Water in the Arkansas River at Dam No. 2 has an average chloride concentration of less than 70 mg/L (ADEQ 2002a), which is significantly lower than chloride concentrations in groundwater that is currently being used for irrigation (ranging up to 1200 mg/L; USGS 1985b).

In addition to the SAFS project, ASWCC will continue its ongoing efforts to address nonpoint source pollution in the Boeuf River and Bayou Macon basins as well as other parts of Arkansas. The ASWCC utilizes the monitoring information discussed in Section 6.1 to establish priorities so that voluntary nonpoint source program activities may be directed toward these priority sources. ASWCC receives federal funding under the Clean Water Act Section 319(h) nonpoint source program. ASWCC will continue to work cooperatively with federal, state, and local partners that assist in implementation of education al programs and watershed protection and restoration projects to restore the designated uses of waterbodies.

The status and expected impact of the SAFS project, in addition to ongoing programs by the ASWCC, satisfies the requirement for reasonable assurances that reductions of nonpoint source loads of chloride are likely to occur.

7.0 PUBLIC PARTICIPATION

When EPA establishes a TMDL, federal regulations require EPA to publicly notice and seek comment concerning the TMDL. Pursuant to a May 2000 consent decree, these TMDLs were prepared under contract to EPA. After development of the TMDLs, EPA prepared a notice seeking comments, information, and data from the general public and affected public. No comments, data, or information were submitted during the public comment period. EPA has transmitted the final TMDLs to ADEQ for implementation and for incorporation into ADEQ's current water quality management plan.

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